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Cover Crop Rollers: A New Component of Conservation Tillage Systems

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Abstract. Rollers may provide a valuable alternative to chemicals for terminating a cover crop. Several producers are now using versions that they have made or have purchased. Most of these producers, however, complain about excessive vibration that is caused by the roller passing over the cover crop. To avoid this excessive vibration, they must limit their operational speed. Experiments were performed to determine if two alternative designs for the blades of the rollers would decrease vibration while maintaining the ability to kill a cover crop. Results showed that a curved blade system or a short-staggered straight blade system significantly reduced vibration as compared to the standard long-straight blade system typically found on rollers. These two alternative blade systems were also found to kill the cover crop as effectively as the long-straight blade system.

Keywords. Conservation tillage, cover crop, implement, residue

Introduction

Between 1990 and 2002, the number of U.S. cropland acres planted without tillage increased from 73.2 million acres to 103.1 million acres (CTIC, 2003). The use of cover crops has contributed to the overall success of conservation systems for many producers. Many studies have recognized the positive benefits of winter cover crops as a component of conservation tillage systems. These include increased water infiltration, reduced runoff, reduced soil erosion, and reduced negative effects of soil compaction (Reeves, 1994; Raper *et al.*, 2000a; Raper *et al.*, 2000b).

Prior to planting the cash crop, the cover crop should be terminated. This should prevent the cover crop from using valuable spring moisture that could be used by the main cash crop after it has been planted. Several methods have been used for this purpose with the most common being the use of chemicals. This option is relatively fast and inexpensive and has quickly become the method of choice. However, planting after a chemical kill can sometimes be difficult if the cover crop was allowed to become too large and has lodged in multiple directions. This may hamper the ability of a planter with conservation tillage attachments from being successful in moving or cutting the residue and placing the seed in a proper soil furrow.

Another method that has often been used to terminate the cover crop is to mow it. This option may also have problems because cover crops can sometimes re-sprout and can compete with the cash crop for available moisture and nutrients. Also, the unattached crop residue can make the planting operation difficult as row cleaners can become clogged with loose residue and require frequent cleaning.

Flattening and crimping cover crops is widely used in South America and is receiving increasing interest in North America. Implements for this purpose are usually round drums with attached blunt blades. The purpose of the blades is to crimp or crush the stems of the cover crops and not cut them. If the stems are cut, the cover crops can re-sprout.

There are multiple benefits of rolling a cover crop (Ashford and Reeves, 2003). First, when the operation is conducted at the correct stage of plant growth, the roller is equally effective as chemicals at terminating the cover crop. Second, the energy required for rolling is significantly reduced from that of mowing, perhaps even as much as tenfold. Third, a flat mat of cover crop is created that lays in the direction of travel. Producers using planters operating parallel or slightly off parallel to this direction have been very successful in obtaining proper plant establishment.

Some North American producers have reported problems with these machines, however, when they have attempted to create or use rollers similar to those used in South America. The main complaint has been the excessive vibration that the rollers transmit to the tractor. The most effective method of alleviating the vibration has been to reduce travel speed. However, most producers find this to be an unacceptable solution due to the much higher speeds that they were able to previously spray their cover crops.

The objectives of this paper are therefore:

- to determine the pressures necessary for rolling and crimping cover crops, and
- to determine if alternative blade designs would reduce vibration while maintaining adequate crimping of cover crops.

Materials and Methods

Experiment 1: Necessary Pressure to Kill Cover Crop

To enhance our understanding of the rolling/crimping process, a series of three experiments were carried out. For the first experiment, an existing prototype roller was used. This roller was a small section of a three-piece roller assembly constructed by [1]Bigham Brothers, Inc. (Lubbock, TX). The small roller (1.14 m width x 0.41 m diameter) was removed from the larger implement and placed on a category 1 toolbar (ASAE, 1998);Fig. 1). A weight bracket was added to the implement so that the amount of weight could be varied.

Figure 1. Small section of a cover crop roller used for Experiment 1 in the soil bins of the NSDL. A weight bracket and two weights are shown mounted on the roller. Also, note the blades mounted on the roller as well as the angle iron mounted between the blades.

The blades on the roller were of 6.4 mm thickness and 0.10 m height and were rigidly attached to the roller drum at seven different locations around the drum with a uniform circumferential spacing of 0.18 m. These blades were blunt and were not designed to cut the cover crop, rather they were designed to crimp it and leave it intact. Between the blades, 8.8 cm angle iron was welded onto the roller to limit the amount of vertical movement of the roller and reduce vibration. The vertical height of this angle iron as it was welded was 5.7 cm.

The first experiment investigated the amount of pressure that was required kill a cover crop. To obtain various pressures on the blades, different amounts of weight were attached to the weight bracket. The overall weight of the roller was 445 kg. Assuming that all of the weight of the roller was suspended over a single blade, the maximum pressure exerted by the roller was 0.61 MPa with no weight attachments. This pressure is slightly higher than the 0.44 MPa blade pressure used by Ashford and Reeves (2002) for their roller. Attaching the weight bracket (45 kg) and

[1] Use of company names or tradenames does not imply endorsement by USDA-ARS or Auburn University.

including two additional weights (90 kg) results in increasing the pressure to 0.80 MPa. Adding four more weights (180 kg) to the machine results in a third pressure of 1.05 MPa.

This experiment was conducted in the outdoor soil bins of the USDA-ARS National Soil Dynamics Laboratory (NSDL) in Auburn, AL on a Vaiden silty clay soil (thermic Aquic Dystruderts) and a Hiwassee clay soil (thermic typic Rhodudults). The roller was attached to a soil bin car which only allowed the roller to contact the cover crop or soil. Travel speed was kept constant at approximately 1.1 m/s.

A cover crop of rye (*Secale cereale* L.) was grown during winter months of 2001 and spring months of 2002 for testing in these two soil bins. The experiment was conducted in early April 2002 when the cover crop was in the soft dough growth stage (Nelson *et al.*, 1995). Measurements of cover crop biomass were taken on a 0.25-m^2 area.

A completely randomized block experiment was conducted with three replications. Three different treatments of applied pressure of 0.61 MPa, 0.80 MPa, or 1.05 MPa were used. The tractor and roller were used in three different lanes in the soil bin with each plot being approximately 1.14 m wide (the width of the roller) x 20 m long.

Measurements of the indentation into the soil by the blades from the roller were made on bare areas of the soil with a ruler. Percent kill measurements obtained by each treatment were made on a weekly basis for four consecutive weeks and compared to a control plot which was not rolled. Percent kill measurements were obtained by using a visual rating system on a 0-100 scale with 0 being no kill and 100 being complete kill.

Cone index and soil moisture were measured immediately after the conclusion of the roller experiment. Cone index was measured on the soil bins with a Rimik (Toowoomba, Australia) hand-held soil cone penetrometer (ASAE, 1999a; ASAE, 1999b). Volumetric soil moisture was also measured in the 0-15 cm depth range using a time-domain reflectometry probe.

Experiment 2: Evaluation of Different Blade Systems in Soil Bins

For the second and third experiments, an experimental roller was designed and manufactured by an Auburn University Mechanical Engineering design class as part of their Capstone Design Project that had the capability of using three different blade systems (Fig. 2). This implement had a diameter of 0.41 m, a width of 0.91 m, and weighed 341 kg. It was mounted on a category 1 toolbar. This toolbar was mounted on a soil bin car which allowed only the roller to touch the cover crop or soil. The roller was operated at a speed of approximately 1.3 m/s.

Figure 2. Small roller used for Experiments 2 and 3. On the left is the long-straight blade system, in the center is the short-staggered straight blade system, and to the right is the curved blade system.

The second experiment consisted of evaluating three different blade types and determining their different vibration characteristics and their crimping capability. The blades were all of 5 cm height and 6.4 mm thickness. This experiment was also conducted in the two outdoor soil bins of the NSDL in a Vaiden silty clay soil and a Hiwassee sandy loam soil.

To expedite the experiments, a sorghum-sudan grass (*Sorghum bicolor,* (L.) Moench) cover crop was grown during the summer months of 2002 and used for the next experiment. Tests were conducted during August, 2002 when the sorghum-sudan grass was in growth stage 3 (Vanderlip and Reeves, 1972). The cover crop was killed when the sorghum-sudan grass cover crop was in a much earlier crop growth stage than the rye in Experiment 1 due to our need to plant our normal winter cover crops for future experiments. Measurements of cover crop kill were made on a weekly basis for three consecutive weeks. Measurements of cover crop biomass were taken on a 0.25-m^2 area.

A completely randomized block experiment was conducted with three replications. Three different treatments of various blade systems were used: (1) long-straight blades, (2) short-staggered straight blades, and (3) curved blades. A unique feature was incorporated into the manufacture of the roller that allowed any of these blade arrangements to be mounted using bolts to threaded sections of the drum. The roller was used in three different lanes in the soil bin with each plot being approximately 0.91 m wide (the width of the roller) x 20 m long. The maximum pressures applied by the roller (0.64 MPa) were similar to those applied by the roller used in Experiment 1 when treatment 1 was conducted (0.61 MPa with straight long blades).

Vibration data was obtained with a Quest Technologies (Oconomowoc, WI) VI-100 Vibration Meter. The vibration sensor was mounted on the frame of the experimental roller perpendicular to the measuring surface to give a vertical acceleration. Seven observations were read from the digital display and were manually recorded for each plot. Acceleration data (m/s^2) was reported in root-mean-square (RMS) values, which is 0.707 of the peak-to-peak acceleration.

Experiment 3: Evaluation of Different Blade Systems in Field

A third experiment was conducted in the field on a Compass sandy loam soil (thermic Plintic Paleudults) and in a concrete-floored shed at the E.V. Smith Research Station near Shorter, AL. This experiment consisted of determining vibration information for each of the three blade systems used on the experimental roller used in Experiment 2. These blade systems were: (1) long-straight blades, (2) short-staggered straight blades, and (3) curved blades. Four replications of each blade treatment were conducted on three surfaces: (1) rye cover crop in field, (2) grassed area, and (3) concrete shed floor. The small roller was attached to the JD 4400 tractor and was operated at a constant speed of approximately 1.3 m/s.

A rye cover crop was grown during winter months of 2002 and spring months of 2003. The experiment was conducted in late April 2003 when the rye cover crop was in a late soft dough stage. Measurements of rye cover crop mass were taken on a 0.25-m^2 plot area immediately after the completion of the experiment as well as weekly measurements of cover crop kill. Measurements of vibration using the Quest Technologies Vibration Meter were also obtained for each blade system on each surface.

Results and Discussion

Experiment 1: Necessary Pressure to Kill Cover Crop

The rye cover crop produced 8040 kg/ha of dry biomass on the Vaiden silty clay soil and 6471 kg/ha on the Hiwassee clay soil. The volumetric soil water was found to be 26.8% in the 0-15 cm range for the Vaiden silty clay soil and 21.1% for the Hiwassee clay soil for this same depth range. The soil strength of the Hiwassee soil was greater than the Vaiden soil throughout the entire soil profile even though neither exhibited signs of root-limiting levels of soil compaction (Fig. 3).

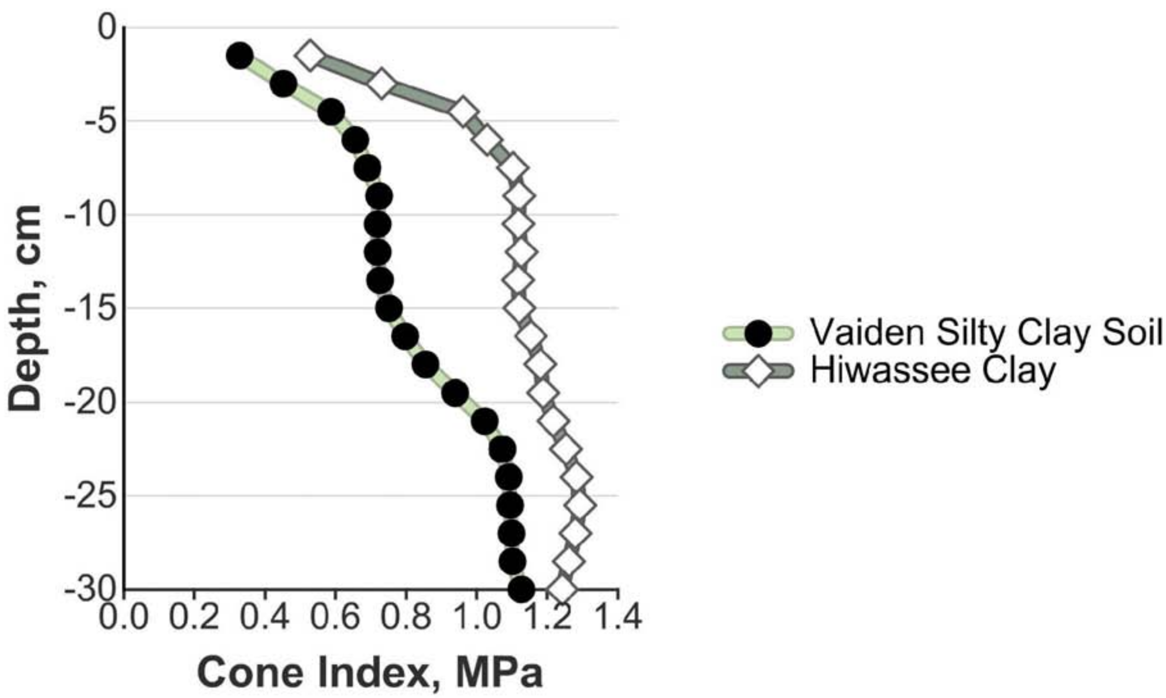

Figure 3. Cone index profile for the Hiwassee clay and the Vaiden silty clay soil.

Analyzing the indentations made by the roller on the soil surface showed a significant effect of soil type (Fig. 4). Statistically significant higher indentations were made in the Vaiden soil as compared to the Hiwassee soil. For the Vaiden soil, 1.05 MPa caused indentations of 13 mm, 0.80 MPa caused indentations of 8 mm, and 0.61 MPa caused indentations of 6 mm. For the Hiwassee soil, 1.05 MPa caused indentations of 11 mm, 0.80 MPa caused indentations of 9 mm, and 0.61 MPa caused indentations of 5 mm.

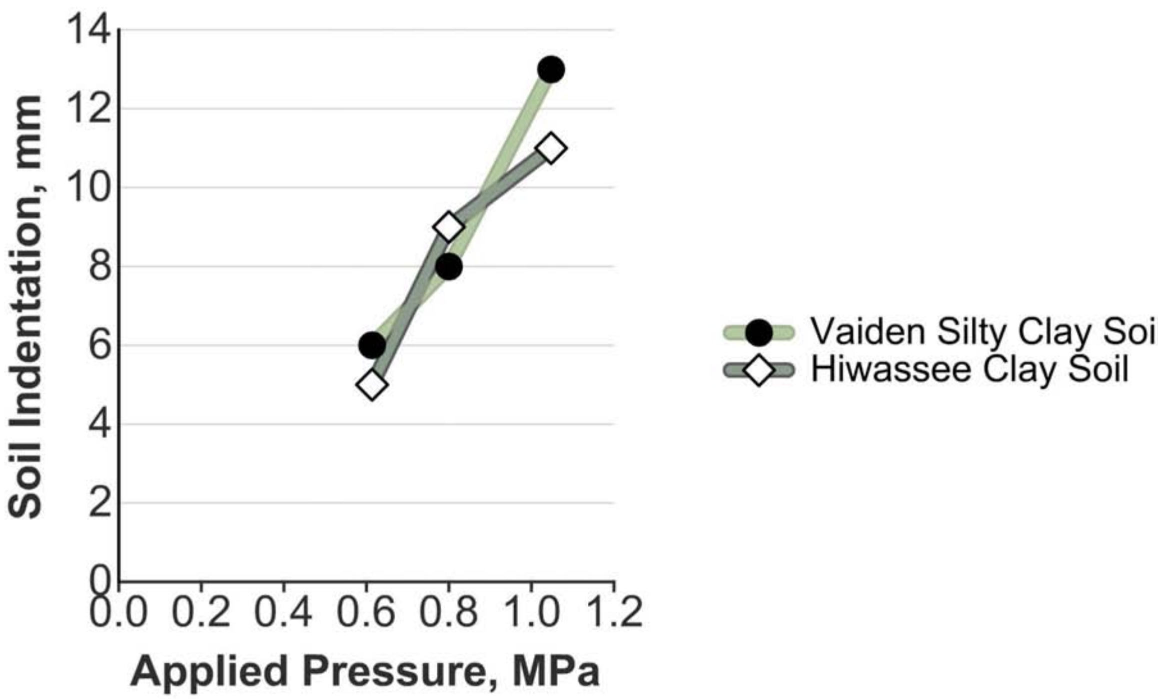

Figure 4. Soil indentations made by the roller in Experiment 1 in the two soil bins. $LSD_{0.1}$ between soils within treatments = 0.6 mm; $LSD_{0.1}$ between treatments within soils = 0.8 mm.

After the cover crop had been rolled down one week, only about 5% of the cover crop had been killed by the use of the roller (Table 1). A statistically significant increase (but not biologically or practically important) was found on the Hiwassee clay soil with the two larger pressures (0.80 MPa and 1.05 MPa) having 6 % kills and the lesser pressure of 0.61 MPa having only a 4.8 % kill. After the second week, the percent kill values had increased to almost 30% for the two higher pressures in the Hiwassee clay causing a statistically higher value of 28.8% as compared to the lower pressure having a 23.2 % kill. The third week of readings found the largest increase in percent cover crop kill with all values going up over 60%. No differences were found during this week's readings. Only a slight numeric increase in percent kill was found by waiting until the fourth week of the readings as most plants had died by this time.

Table 1. Percent kill for the rye cover crop for Experiment 1.

	% Cover Crop Kill							
	Vaiden silty clay soil				Hiwassee clay soil			
	0.61 MPa	0.80 MPa	1.05 MPa	*$LSD_{(0.10)}$*	0.61 MPa	0.80 MPa	1.05 MPa	*$LSD_{(0.10)}$*
Week I	5.5	5.5	6.2	*ns**	4.8 b	6.0 a	6.0 a	*0.89*
Week II	27.0	28.2	30.2	*ns*	23.2 b	28.8 a	28.8 a	*4.17*
Week III	63.0	62.8	68.8	*ns*	66.2	66.8	71.0	*ns*
Week IV	64.5	67.5	63.5	*ns*	75.0	71.2	73.8	*ns*

**ns* indicates lack of statistical significance at the 0.10 level.

The results from Experiment 1 indicate that the pressure necessary to crimp or crush a rye cover crop was not significantly important in the range tested. All of the pressures tested (from 0.61 MPa to 1.05 MPa) were equally able to kill the rye cover crop after a three- to four-week period. These results correlate well with Ashford and Reeves (2003) which found that cover crop growth stage was the most important factor in determining the effectiveness of various methods of killing cover crops.

Experiment 2: Evaluation of Different Blade Systems in Soil Bins

Greatly reduced masses of sorghum-sudan grass cover crop were grown during the summer months of 2002 as compared to the previous winter's rye cover crop. The sorghum-sudan grass cover crop grown on the Vaiden silty clay soil produced 2526 kg/ha while it produced 3862 kg/ha on the Hiwassee sandy loam soil. The volumetric soil water was found to be 21.0% in the 0-15 cm range for the Vaiden silty clay soil and 7.7% for the Hiwassee sandy loam soil for this same depth range.

The percent kill values measured each week were reduced throughout the experiment as compared to those measured in Experiment 1. These small percentages of kill were not unanticipated due to the early growth stage of the cover crop. No measurements could be made on Week I due to inclement weather. For every other week of the experiment, no differences were found between the three different blade systems used on the roller.

Table 2. Percent kill for the sorghum-sudan grass cover crop for Experiment 2.

	% Cover Crop Kill							
	Vaiden silty clay soil				Hiwassee sandy loam soil			
	Straight	Staggered	Curved	$LSD_{(0.10)}$	Straight	Staggered	Curved	$LSD_{(0.10)}$
Week I	-	-	-	-	-	-	-	-
Week II	5.3	5.0	6.0	*ns*	7.0	5.3	5.3	*ns*
Week III	6.7	6.7	6.7	*ns*	7.7	8.7	7.3	*ns*
Week IV	16.7	16.0	14.7	*ns*	22.0	22.7	18.0	*ns*

**ns* indicates lack of statistical significance at the 0.10 level.

Non-replicated measurements taken with the Quest Technologies Vibration Meter on the Vaiden soil bin showed benefits of using either the curved blade or the short-staggered straight blade arrangement as compared to the long-straight blade arrangement (Fig. 5). A large increase in the vibration level was found using the long-straight blade on a nearby grassed area as compared to using this same blade on the cover crop. This increase in vibration is undoubtedly due to increased soil strength in the grassed area as compared to the Vaiden soil bin which had been previously tilled and contained significant levels of soil moisture.

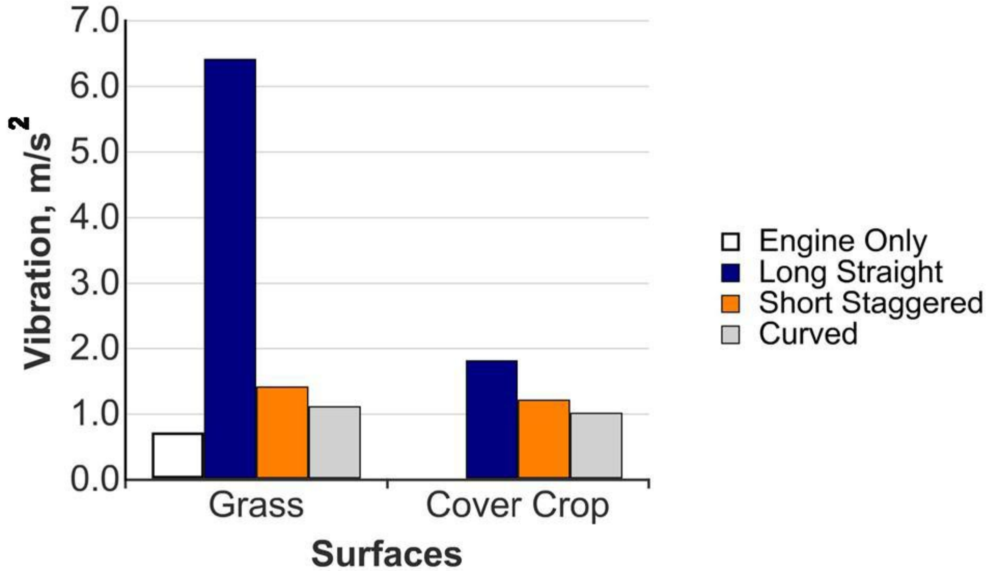

Figure 5. Vibration data obtained with the experimental roller in Experiment 2.

Experiment 3: Evaluation of Different Blade Systems in Field

During the winter months of 2002 and spring months of 2003, the rye cover crop produced 3404 kg/ha. By the time the rolling experiment was conducted in late April of 2003, the cover crop had already started to die. Partly due to this timing and partly due to the success of the blade systems, there were no measurable differences in percent kill for the roller. All blade treatments performed equally well in the field experiment with all achieving a 100% kill within one week after the rolling operation.

Table 3. Percent kill for the rye cover crop for Experiment 3.

	% Cover Crop Kill			
	Long-Straight Blades	Short-Staggered Straight Blades	Curved Blades	$LSD_{(0.10)}$
Week I	100	100	100	*ns*

**ns* indicates lack of statistical significance at the 0.10 level.

Statistically significant vibration results were found for each of the blade systems on each of the surfaces tested (Fig. 6). As expected, the highest levels of vibration were measured on the concrete floor by all three blade treatments. On the concrete surface, the long-straight blade system recorded the highest value of almost 200 m/s^2. The grassed area recorded the next highest vibration values which were statistically greater than those recorded for the rye cover crop area.

The long-straight blade system consistently recorded the maximum values for each surface tested. Although the short-staggered straight blade system recorded statistically higher vibration values as compared to the curved blade system, both of these two treatments were much smaller as opposed to the long-straight blade system for either the grass or cover crop surface.

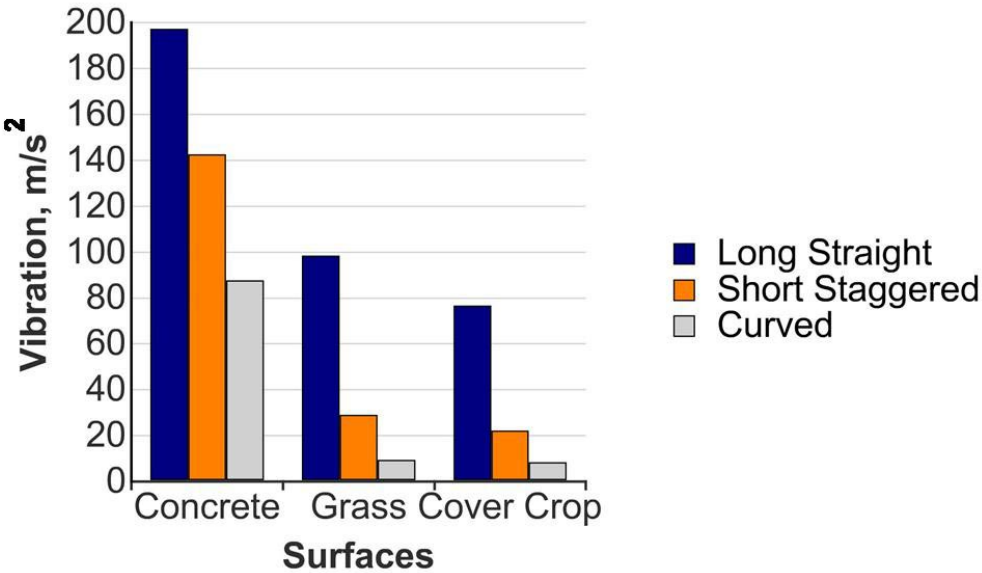

Figure 6. Vibration data obtained with the experimental roller for Experiment 3. $LSD_{0.1}$ between surfaces within treatments = 6.9 m/s^2; $LSD_{0.1}$ between treatments within surfaces = 5.8 m/s^2.

Conclusions

- Small prototype rollers were used which provided adequate pressures for rolling and crimping cover crops and to provide for adequate kill. The minimum pressure of 0.61 MPa provided similar kill values of the cover crop as those resulting from the much larger pressure of 1.05 MPa.
- Two alternate blade systems for the roller, a curved blade system and a short-staggered straight blade system, were found to reduce vibration significantly over the standard long-straight blade system typically used on these implements. The curved blade system recorded significantly reduced vibration as compared to the other blade systems on concrete, on grass, and in a cover crop. All blade systems performed equally well in killing the cover crops in field and soil bin experiments.

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